PSYCHE.

EXPERIMENTS UPON THE EFFECT OF COLD APPLIED TO CHRYSALIDS OF BUTTERFLIES.

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(*Continued from p.* 6.)

With every experiment, however similar the conditions seem to be, and are intended to be, there is a difference in results, and at present the reason therefor does not appear. For example, in 1878, the first butterfly emerged on 14th day after removal from the ice, the period being exactly what it is at its longest in this species in nature, with an occasional exception. Others emerged at 19 days and several at intervals up to the 96th day after ice. In 1879, the emergence began at 8 days, and by 12 days all which came out this year had appeared, except three belated individuals at 22, 40 and 50 days. In previous experiments, no matter what the species, the butterflies had not emerged till after the natural period of the chrysalis had passed, after removal from the ice. In this one, either the cold had not fully suspended the changes which the pupa undergoes in the chrysalis, or these changes were hastened by some other cause after the chrysalids were taken from the ice. In the first experiment, apparently, the changes were absolutely suspended as long as the cold remained.

It might be supposed that the application of heat to the overwintering chrysalids would precipitate the appearance of the summer form of *P. ajax*, or change the butterflies so that while they had the shape of *telamonides* they should have the coloration of *marcellus*. But I have not found this to occur. I have been in the habit, for several years, of placing the chrysalids in a warm room or in the greenhouse, early in the winter, so causing the butterflies to emerge in February, instead of in March and April, as they would otherwise do. But the winter form has invariably emerged from such chrysalids.

3. In June 1879, I obtained eggs of *Grapta interrogationis*, laid by form *umbrosa*, in confinement. As the chrysalids formed, and at intervals of from 6 to 24 hours after pupation, they were placed in the ice box. After 14 days I removed all but five, which were left 6 days longer. Several were dead at the end of the 14 days. Temperature most of the time about 35° F. [1°.7 C.], but a little higher for a few hours each day, as the ice melted, reach-

ing then 40° to 45° F. [4° to 7° C.]. I obtained from the 14-day lot seven perfect butterflies, 3 ♂ 4 ♀ ; from the 20-day lot five, 4 ♂ 1 ♀ ; every one *umbrosa;* and nearly all had changed in one striking particular. In the normal *umbrosa*, of both sexes, the fore wings on upper side have, on costal margin next inside the broad border of hind margin, and separated from it by a considerable space of fulvous, a dark patch which ends a little below the discoidal nervule ; inside the same border at inner angle is a similar patch lying on the submedian interspace. Between these two patches, across all the median interspaces, the ground is fulvous, but very slightly and faintly clouded with black. Indeed, this clouding would usually not be noticed.

I find that in all the four ♀ exposed to cold 14 days, there is present a *broad black band crossing the entire wing*, continuous, of uniform shade, covering the two patches and intervening space, and almost confluent with the marginal border from end to end, only a streak of obscured fulvous anywhere separating band and border. In the other female, being from chrysalis exposed 20 days, the band is present, but while broad and covering the space between the patches, it is not so dark as in the other examples, and includes against the border a series of obscured fulvous lunules. This is like some normal females, and this female, though longest exposed, therefore is essentially unchanged.

In all the males, the patches are diffuse, those at apex almost coalescing with the border. In the three males from the 14-day lot, these patches are connected by a narrow dark band (very different from the broad band of the females), which occupies the same position as the clouding in the normal male, but blackened and somewhat diffused. In the four examples from the 20-day lot, this connecting band is scarcely as deep colored and continuous as in the other three. Beyond this change on the submarginal area, whereby a conspicuous band is created where naturally would be only the two patches and a faint cloudiness over the intervening fulvous space, I see no difference between these examples of both sexes and a long series of natural ones placed beside them, so far as relates to the upper surface.

On the under side, all the males are of the same type, the colors intense. There is considerably more red, both dark and pale, over the whole surface than in the series of natural examples ; these latter discovering shades of brown, over which is a bluish or lilaceous flush. In the females I discover no change on under side.

It appears that 14 days was as effective in producing changes in case of this *Grapta*, as a longer period. In fact, the most decided changes were found to be in the females exposed least. It appears also that cold will produce change if applied after the chrysalis has hardened. In 1878, I put *Grapta* chrysalids on ice at from 10 minutes to 6 hours after pupation, and while some were quite soft, — and lost every one of them, although some chrysalids of *P. ajax* in same box, and in part exposed very shortly after pupation, were not injured. It also appears that cold may change certain markings only, and that the females were most susceptible to the influence.

The resulting butterflies were all *um-*

brosa, though both forms of the species might have been expected to appear. In breeding from eggs laid by *umbrosa* in a former year, I obtained both forms of the butterfly, viz.: 11 *umbrosa* and 6 *fabricii*. But from this single experiment it cannot be determined whether any change of form was brought about.

4. In 1877, a lot of eight chrysalids of *P. ajax*, all under 12 hours from pupation, were put on ice and left there 24 days. (They were placed on top of the ice, but in all later experiments I have placed them under it, in the bottom of the box.) The temperature was irregular, and as I was absent from home nearly all of the time, and had to leave the box in charge of servants, I felt no certainty that the ice had not been supplied irregularly, or that there had not been intervals during which there was no ice in the box. But from these chrysalids there came 5 ♂ 3 ♀ butterflies. Of these, one was *telamonides* unquestionably, in color and markings; all the rest were between *telamonides* and *marcellus*. Two other chrysalids, on ice 23 days, in the box at same time with the above mentioned eight, gave *telamonides*. But three more, exposed 26 days, and 1 hour from pupation when placed in the box, all gave unchanged *marcellus*.

In the box at same time were 6 chrysalids of *G. interrogationis*, and all of them gave unchanged *umbrosa*.

5. During the same season, 1877, I exposed six *P. ajax* chrysalids, keeping the temperature as nearly as possible at 33° F. [0.6° C.]. One was 1 hour from pupation, and remained in the box 5 days; one same age, remained in box $2\frac{3}{4}$ days; three at 3 hours old, for 8 days, and one, age omitted, for 6 days. All these produced *marcellus*, and therefore they had not been affected by the cold.

6. In 1877, I had placed several chrysalids of *Lycaena pseudargiolus* in the ice box, thinking that I might thus obtain the form *violacea*, which is the winter form of the species. On 8 Aug., 31 days after the chrysalids were removed from the box, a female emerged, in some respects considerably unlike either of the forms. The common series of dark streaks and points across the disks was wholly wanting, though the stripes across the ends of cells were present; and the marginal crescents were large and black — far more conspicuous than is ever seen in the natural *pseudargiolus*, and still very unlike *violacea*. The general coloration of both surfaces was that of the usual female *pseudargiolus*. All the other chrysalids were found to be dead.

In Can. Entom., v. 7, p. 236–240, I gave an account of the first experiments made by me in exposing chrysalids to cold, the subject being *P. ajax*. The chrysalids were placed in the ice box, but were subsequently removed to the ice house and left for two months after forming, but on returning home after a long absence I found the ice had wholly melted. The chrysalids had at first been subjected to a low temperature in the box, but as the ice in the house failed, the temperature had risen so that when I examined the tin cases which had held the chrysalids, many butterflies were found alive therein in a crippled state. About one half the butter-

flies that emerged from this lot were completely changed, being *telamonides* and *walshii*, and about half the rest were partly changed. It was observed also that the butterflies were generally smaller than the average *marcellus*. I have not been able to subject chrysalids to cold for a very long period, for the reason that ice fails us in midsummer, it having been put up when thin and of poor quality, owing to our moderate winter climate. Indeed, in some seasons we get no ice at all, as the streams do not freeze over. On more than one occasion the period of exposure has abruptly terminated, and much earlier than I had intended, by the failure of the ice.

Summary of the experiments with *P. ajax*.

In 1877: chrysalids 1 to 3 hours old exposed from $2\frac{3}{4}$ to 8 days. Temperature 33° + F. [0.6° C.]. No change effected.

In 1878: chrysalids 10 to 15 minutes old, and at intervals up to 1 day, and then daily to 8th day from pupation; exposure from 19 to 5 days. Result: one *telamonides* or *walshii* from chrysalis 12 hours old, 11 days exposure; one *walshii* from chrysalis 2 hours old, 11 days exposure; one *telamonides* from chrysalis 3 days old, 16 days exposure; all the rest unchanged, but the periods of emergence remarkably prolonged. Temperature 33° + F. [0.6° C.].

In 1879: chrysalids not less than 12 hours old nor over 24 hours; exposed 14, 20, and 24 days. Result: the period of emerging greatly precipitated in nearly all cases. From the 14-day lot there was no change or only a partial one; from the 20-day lot, one half were changed, the rest partly or not at all; from the 25-day lot all were changed. Temperature 33° + F. [0°.6 C.].

In 1877: chrysalids under 12 hours old, but the minimum not noted; exposure 24 days. Temperature 40° F. [4.4° C.] and upwards, irregular. Result: one changed fully, seven partly; some others subjected to same conditions for 23 days were fully changed; others at 26 days not at all.

In 1875: chrysalids stated in my note book to have been exposed "as formed," but the exact age not given; exposed for 30 to 60 days; temperature at first about 32° F. [0° C.], afterwards uncertain. Result: 50 per cent. fully changed, 25 per cent. partly, rest not.

General conclusions: —

1. *P. ajax*. The longer the exposure under a low temperature the more decided the change, but 25 or 30 days seem quite sufficient in many cases, and changes have been produced by exposure for 20, 16 and 11 days; no changes recorded at less than 11 days; while exposure at 8 days and less has produced no effect except in some cases to prolong the chrysalis period.

2. The longest interval between pupation and exposure to cold when any change has resulted, has been 3 days. In all instances beyond that no change has been produced. The shortest interval has been two hours, and in this instance the butterfly was changed to *walshii*, which is a change more extreme than to *telamonides*. Most chrysalids exposed so early die in the process, but as many changes have been effected when the age of the chrysalis at exposure has been from 12 to 24 hours, I believe that to be the most satisfactory period. The chrysalis has then become hard-

ened, and the growth of the organs of the pupa probably then begins, and their direction may best be turned by the cold then applied.

3. The effect of the cold is to albinize the butterfly, the black area being constantly reduced.

4. Cold has failed to change the shape of the wings, its influence being confined to coloration and markings; the frontal hairs of the head have also been changed; and the sexes are equally susceptible.

5. *Grapta interrogationis*. 14 days exposure after the chrysalids have hardened, has been found sufficient to produce changes; and the females were most susceptible to the influence of cold.

6. With different species the degree of temperature required to produce the most decided change varies. I have succeeded best with *Phyciodes tharos*, at 40° F. [4.4° C.]. At 32° F. [0° C.] have destroyed many *Grapta* chrysalids, but this may have been principally because the chrysalis was too tender when exposed. With *P. ajax* 32° to 40° F. [0° to 4.4° C.] seems a proper temperature.

My experiments with *Ph. tharos* are given in Can. Entom., v. 9, p. 4, and p. 204–206. Also in Butterflies of N. A., v. 2, pt. 7. In the former, a complete change was brought about, and every butterfly emerged in the winter form. Temperature about 40° F. [4.4° C.], and continued for 7 days, the chrysalids being 3, 6, 9 hours old when exposed, and before several had hardened. In the second experiment, the temperature was about 32° F. [0° C.]; the chrysalids were 10 minutes to 9 hours old, and the exposure was about 20 days. It was found that the butterflies emerging from chrysalids which had been from 1 to 9 hours old were completely changed; some which had been from 30 to 60 minutes old were not changed, while others of same lot were greatly suffused. I concluded that with this species it was not necessary that cold should be applied after the chrysalids had hardened, in order to change the form.

REVIEWS.

Professor Eduard Brandt's interesting papers upon the nervous system of insects, which appeared during 1878 and 1879 [see Rec., nos. 1451–1458] in the *Horae Societatis Entomologicae Rossicae*, are valuable additions to the literature of the subject. The amount of research upon which the author's conclusions are based, can be best understood, perhaps, by considering that Professor Brandt examined the nervous system of nearly a thousand species of adult insects, and of about one hundred and twenty-five species of larvae, and that he studied the metamorphoses of the nervous system in more than fifty species. Up to the time of appearance of Professor Brandt's papers but little had been published upon this subject; for example, the metamorphoses of the nervous system had been traced in only eight species (four lepidoptera and four coleoptera). Many important facts were ascertained in his studies, and the papers, published both in German and in Russian, and fully illustrated with photolithographic plates, present the facts in a systematic and carefully condensed form. *G. D.*